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The prediction of thriving in elite sport: A prospective examination of the role of psychological need satisfaction, challenge appraisal, and salivary biomarkers

Daniel J. Brown[a,b], Rachel Arnold[a*], Martyn Standage[a],
James E. Turner[c], and David Fletcher[d]

[a] Centre for Motivation and Health Behaviour Change, Department for Health, University of Bath, United Kingdom
[b] School of Sport, Health and Exercise Science, University of Portsmouth, United Kingdom
[c] Centre for Nutrition, Exercise and Metabolism Department for Health, University of Bath, United Kingdom.
[d] School of Sport, Exercise, and Health Sciences, Loughborough University, Loughborough, United Kingdom

*Correspondence concerning this article should be addressed to Rachel Arnold, Centre for Motivation and Health Behaviour Change, Department for Health, University of Bath, Claverton Down, Bath, BA2 7AY, United Kingdom. Telephone: 4412-2538-5107. E-mail: R.S.Arnold@bath.ac.uk

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Abstract

Objectives. To examine (i) whether levels of, and changes in, athletes' basic psychological need satisfaction (BPNS) and challenge appraisals predicted in-match thriving; and (ii) if salivary biomarkers could be defined that were related to thriving.

Design. Prospective study design.

Method. Fifty-one elite male hockey players (M_{age} = 24.94 years, SD_{age} = 4.73) completed questionnaires measuring their BPNS and challenge appraisals on seven consecutive days prior to a competitive match, as well as providing saliva samples immediately on waking, and then + 0.5, + 3, and + 5.25 hours on the day of the match. Saliva was assayed for catabolic (i.e., cortisol) and anabolic (i.e., dehydroepiandrosterone [DHEA]) hormones. In-match thriving was assessed retrospectively using measures of subjective performance and well-being.

Results. Latent growth curve modelling showed pre-match levels of BPNS and challenge appraisals to positively predict thriving. Although not statistically significant, small and moderate negative associations were found for thriving with cortisol concentration (+ 5.25 hours sample) and total cortisol exposure across the morning of the match, respectively. DHEA concentration shared a small positive, yet non-significant, association with thriving.

Conclusions. Athletes' pre-match levels of BPNS and challenge appraisal predict in-match thriving; thus, offering potential mechanisms through which both high-level performance and the experience of well-being can be facilitated. Furthermore, associations suggest that total cortisol exposure across the morning of the match, and cortisol and DHEA levels in pre-match samples may offer sport science and sports medicine practitioners potential biomarkers for thriving. Future research is required to substantiate this initial finding.

Keywords: cortisol, dehydroepiandrosterone, Monte Carlo power calculations, performance, thrive, well-being

Introduction

With growing calls in elite sport to ensure the protection and promotion of athlete well-being whilst in pursuit of optimal performance, it is essential that research establishes the factors that can predict the joint occurrence of these outcomes. A construct that may assist in this pursuit is *thriving*. Individuals who are thriving have been described as experiencing full or holistic functioning[1, 2] and, within sport, this experience has been characterized by the simultaneous display of high-level performance and the experience of well-being.[3, 4] More specifically, thriving performers have been identified as those who report highest levels across subjective performance (via performance satisfaction), eudaimonic well-being (via subjective vitality), and hedonic well-being (via positive affect) dimensions.[3]

Literature on thriving in sport has begun to identify the psychosocial variables important for understanding why some performers thrive whereas others do not. For example, exhibiting a readiness for challenge was shown to enable thriving during a geographic transition,[5] and operating within an integrated, inclusive, and trusting environment was suggested to facilitate thriving within a professional team sport.[6] To explain these associations and understand *how* these factors influence thriving, it is necessary to examine the mechanistic variables at play (i.e., the proximal determinants of thriving). Two candidate variables previously suggested to determine thriving are basic psychological need satisfaction (BPNS) and challenge appraisal.[1, 2] BPNS describes the degree to which individuals experience satisfaction of the basic psychological needs for autonomy (i.e., need for volitional, congruent, and integrated functioning), competence (i.e., need to feel effectance and mastery), and relatedness (i.e., need to feel socially connected and cared for).[2] Scholars have argued that the satisfaction of these three needs reflects human thriving in the deepest sense and therefore such satisfactions predict indicators reflective of wellness and optimal functioning.[2] Challenge appraisal describes a type of judgment made by humans when faced with a situation that has relevance for personal well-being.[7] More specifically, challenge appraisals occur when the personal significance of the stressor is in proportion to the available coping resources, resulting in the belief that gain or growth may occur.[8] Perceiving a situation as a challenge is, therefore, likely to encourage engagement and create opportunities for positive change.[9] Within a sport setting, Brown et al.[3] have

shown support for a positive, predictive relationship between BPNS, challenge appraisal, and membership to a thriving profile. Yet, these findings were limited by participants completing, at a one-off time-point, measures of the study variables retrospectively after their sporting encounters. Thus, when using this approach, it was possible that the performers' assessments of pre-match variables were distorted by the match outcome. To advance this research, it is therefore necessary to conduct discrete assessments of pre-match variables and subsequent outcomes.

Both BPNS[2] and challenge appraisal[7] are dynamic and fluctuate over time. Indeed, within-person daily fluctuations in BPNS and challenge appraisal have been found to predict pre- post-practice changes in well-being[10] and daily affective states,[11] respectively. Within this work, changes have typically been considered on a cyclical basis (i.e., from day-to-day) with limited consideration given to how state-based perceptions alter towards a focal event (e.g., an important match). The absence of these prospective studies tells us little about how levels of BPNS and challenge appraisal fluctuate in advance of a match (e.g., increase linearly, oscillate between high and low levels), and whether the nature of such changes has an impact on 'in-match' outcomes such as thriving. Within the context of the present study, it is anticipated that there will be changes in players' BPNS and challenge appraisal contingent on their daily involvements with their sport, and the proximity of the match. For example, training sessions occurring in the days preceding the match were anticipated to strengthen feelings of closeness between players, and to provide an opportunity for individuals to participate in their sport willingly and demonstrate proficiency in their skillset. Furthermore, levels of BPNS are likely to increase in the days closest to a match as a player mentally prepares themselves for their upcoming sporting involvement (e.g., using self-talk to enhance perceived competence).[12] Levels of challenge appraisal are also anticipated to increase as the match approaches given the motives and personality of elite athletes. To elaborate, previous research with elite athletes has documented their insatiable desire to compete at the highest-level given the opportunity it affords them to improve and increase their perceived standing in sport.[13] Irrespective of whether the players participate for personal development or competitive reasons, both options would present the match as an opportunity for growth, and it is likely that players' perceptions of their sport as a challenge will become more intense/apparent as the match approaches and expectations escalate.

In addition to the use of psychosocial variables to predict thriving, researchers have suggested that a physiological mechanism may exist for thriving and that physical thriving could be investigated via an individual's hormonal response to a stressful situation.[14, 15] More specifically, thriving is hypothesized to occur when a greater amount of anabolic hormones (i.e., those involved in restorative processes), rather than catabolic hormones (i.e., those involved in protective processes), are released in a stress response.[14] To examine the effect of the simultaneous secretion of anabolic and catabolic hormones, researchers have derived a ratio of both hormone types, known as anabolic balance.[15] Two hormones that have been used to examine these effects are dehydroepiandrosterone (DHEA; anabolic) and cortisol (catabolic). DHEA concentration increases significantly in response to acute stress[16] and has been suggested to have wide-ranging functions including positive effects on immune function and well-being.[17] Secretion of cortisol also increases acutely in anticipation of a threat and is thought to act by diverting energy away from non-essential bodily functions and redirecting resources.[18] In addition to considering the ratio in which these hormones are released, Epel et al.[14] have argued that the dampening of the acute cortisol response to a stressor may be associated with thriving, as a reduced response would demonstrate an individual's habituation and a perceived ability to cope with the demand. Despite these suggestions, to date, only one study exists that has examined anabolic balance in sport[19] and no known studies have tested the physiological mechanism of thriving in performance settings.

Addressing the aforementioned gaps in the literature, this study sought to examine (i) whether levels of, and changes in, athletes' BPNS and challenge appraisals predicted in-match thriving and (ii) if salivary biomarkers could be defined that were related to thriving. It was hypothesized that (i) higher levels of, and increases in, BPNS and challenge appraisal would positively predict in-match thriving; (ii) DHEA concentration and the ratio of DHEA:cortisol (i.e., anabolic balance) immediately before the match would be positively related to in-match thriving; and (iii) total cortisol exposure across the morning and cortisol concentration immediately before the match would be negatively related to in-match thriving.

Methods

Following institutional ethical approval (EP 14/15 200), elite male field hockey teams were

identified based on their involvement in international or national level competition. The head coaches and players from three teams provided informed consent, and the coaches then helped to select a match prior to which it was logistically feasible to collect data. Recruiting participants from three teams was deemed adequate for the present study given that (i) this represented over a fifth of the teams competing at this level within the geographic vicinity of the research site; (ii) the logistical complexity inherent in conducting this interdisciplinary study; and (iii) the lack of physical and financial resources available to conduct the work in other sites across the country. Fifty-one players (M_{age} = 24.94 years, SD_{age} = 4.73) took part, with an average of 16.89 (SD = 5.92) years' experience playing hockey. All playing positions were represented.

Six days prior to the match, participants were e-mailed a hyperlink to a multi-section questionnaire. Participants were asked to complete the questionnaire online on that and each of the next five evenings, and in paper format on arrival at the match. The questionnaire contained brief, modified scales to assess BPNS and challenge appraisal, and the participants completed the scales in relation to how they felt *at that time* about their hockey involvement. BPNS was assessed using three items from the Basic Needs Satisfaction in Sport Scale (BNSSS),[20] with the items selected via item response theory analysis conducted on responses previously collected from 535 sport performers.[3] The median α for the composite score for BPNS was .79. Challenge appraisal was assessed using the two-item version of McGregor and Elliot's[21] task construal measure (median r across time-points = .90).

At a training session occurring > 48 hours prior to the match, participants were provided four saliva collection tubes labelled with the match day sampling times. Saliva was collected by the passive drool technique[22] (3-minute collection) into pre-weighed centrifuge tubes (FisherbrandTM; Fisher Scientific, Loughborough, UK), and participants were asked not to eat, drink, or brush their teeth in the hour before sampling.[23] Saliva samples were provided by participants on the day of the match immediately on waking, and then + 0.5 hours (M = 00:29, SD = 00:01), + 3 hours (M = 02:57, SD = 00:23), and + 5.25 hours (M = 05:18, SD = 00:35) to partly capture the diurnal rhythm of cortisol release and, in particular, the cortisol awakening response.[24, 25] Participants were asked to write down the exact time at which samples were provided and, where possible, waking time was

verified using data collected from a waist-worn ActiGraph GT3X+ (ActiGraph LLC, Pensacola, FL) triaxial accelerometer. The + 5.25 hours sample coincided with completion of the pre-match questionnaire (collected immediately before commencing match warm-ups). Samples were collected from participants prior to the match and stored at 4 ºC until being processed within the following three days. During processing tubes were centrifuged at 2000 × g for 10 minutes to remove particulate matter, and the saliva was aliquoted into micro-centrifuge tubes (Eppendorf, Hamburg, Germany) and stored at −20 ºC until assay. Salivary cortisol and DHEA levels were analyzed in duplicate using commercially available ELISAs according to manufacturer instructions (Salimetrics, Newmarket, UK). Absorbance values were measured using a microplate reader (SPECTROstar Nano; BMG Labtech, Ortenberg, Germany). To provide a robust assessment of total cortisol exposure across the morning of the match, cortisol levels in the four samples were used to calculate the area under the curve using the trapezoid method relative to ground. The ratio of DHEA:cortisol was calculated using data from the + 5.25 hours sample to provide a pre-match assessment of anabolic balance.

Post-match, participants completed a questionnaire to assess their experience of thriving. In accordance with literature,[3] thriving was assessed by measuring subjective performance, positive affect, and subjective vitality. Specifically, participants were asked to rate their satisfaction with their performance in the match.[26] Positive affect was assessed using the International Positive and Negative Affect Schedule Short Form (I-PANAS-SF),[27] with participants requested to report the regularity with which they experienced five emotional descriptors during the match ($\alpha = .71$). Finally, participants completed an abbreviated version of the Subjective Vitality Scale (SVS),[28] which required them to respond to how accurate four statements were in relation to their match experiences ($\alpha = .91$).

Latent growth curve modelling (LGM) was used to examine changes in BPNS and challenge appraisal in the week leading up to the match, and the effect these changes had on in-match thriving. Time was centered on match day and the intercept factor, therefore, represented the level of the variables reported immediately pre-match. The first step in the analysis was to ascertain the best fitting growth model for each of the variables using intercept-only, linear, and quadratic growth models. Models were compared using the Akaike's Information Criterion (AIC) and the Bayesian Information Criterion (BIC), with smaller AIC and BIC values indicating a better fitting model.[29]

Where a difference of < 2 BIC was identified between models, the difference was not considered worthy of mention, and the model with the lower AIC was selected.[30]

The second step in the analysis was to determine whether the latent growth factors for BPNS and challenge appraisal predicted in-match thriving. Thriving scores were computed from a measurement model (see Supplementary Material) and then modelled as a manifest distal outcome variable in two growth models (i.e., one for BPNS and one for challenge appraisal; see Supplementary Material). Paths between the intercept and slope growth factors and thriving were tested for statistical significance. Model fit was determined using the Comparative Fit Index (CFI), the Tucker Lewis Index (TLI), and the Root Mean Square Error of Approximation (RMSEA). Acceptable values were close to or above .90 for CFI and .95 for TLI, and close to or below .08 for RMSEA; however, it is commonly acknowledged that latent growth models display poor fit against conventional criteria.[31] The relationships between the salivary variables and thriving were determined by correlating thriving with each variable individually. The decision to examine the correlations individually was made as portions of the data were included in multiple variables (e.g., total cortisol exposure and cortisol concentration). Pearson correlations of .1, .3, and .5 were interpreted as small, medium, and large, respectively.[32] LGM and correlation analyses were conducted in Mplus 8.2[33] using the Full Information Maximum Likelihood Robust (MLR) estimation to account for any missing data and non-normality. To test the plausibility of the effect sizes derived from our design and analytical approach, we conducted post hoc power analyses using Monte Carlo[34, 35] studies against the threshold for desirable power of 0.80; example inputs from these studies can be viewed in the Supplementary Material. In addition to the main analysis, changes in cortisol concentration across the four samples were analyzed using repeated measures ANOVA in SPSS 25.[36]

Results

Of the 51 participants who commenced participation in the study, seven were excluded from the final data set because they either did not play in the match (n = 5) or they did not complete the post-match questionnaire (n = 2). Descriptive statistics for the remaining 44 participants are presented in Table 1. Daily survey completion rates across the sample ranged from 66-100%, with individual participants providing an average of five responses. Results from the LGM showed the intercept-only

growth model to provide the best fit to the BPNS data (Table 2). The BPNS intercept mean was significant suggesting that levels of need satisfaction immediately pre-match were significantly different from zero ($M_{intercept}$ = 6.22, p < 0.001, power = 1.00). Furthermore, significant variability was found in these pre-match BPNS scores ($Var_{intercept}$ = 0.35, p = 0.006, power = 1.00), indicating between-person differences prior to the match. When thriving was added as a distal outcome to the intercept-only growth model, a significant positive regression path was found between the intercept growth factor and thriving ($\hat{\beta}$ = 0.73, p = 0.034, $\hat{\beta}^{standardized}$ = 0.36, R^2 = 13%, power = 0.71), showing that higher pre-match BPNS was associated with higher levels of in-match thriving.

A linear growth model was identified as the best fitting model for challenge appraisal (Table 2). The challenge appraisal intercept mean was significant suggesting that levels of challenge appraisal immediately pre-match were significantly different from zero ($M_{intercept}$ = 6.33, p < 0.001, power = 1.00). Furthermore, significant variability was found in pre-match challenge appraisal ($Var_{intercept}$ = 0.48, p = 0.005, power = 1.00), indicating between-person differences pre-match. The slope growth factor showed a significant increase in challenge appraisal as the match approached (M_{slope} = 0.03, p = 0.040, power = 0.61) and since the slope variance was not significant (Var_{slope} = 0.00, p = 0.160, power = 0.35), this suggests that all participants followed a similar trajectory around the mean growth curve. When thriving was added as a distal outcome to the linear growth model, a significant positive regression path was found between participants' pre-match challenge appraisal and in-match thriving ($\hat{\beta}$ = 0.58, p = 0.018, $\hat{\beta}^{standardized}$ = 0.33, power = 0.48), indicating that participants who reported greater levels of challenge appraisal were more likely to thrive in the match. A negative, non-significant regression path was found between the rate of change in challenge appraisal and thriving ($\hat{\beta}$ = -3.23, p = 0.469, $\hat{\beta}^{standardized}$ = -0.15, R^2 = 11%, power = 0.06), suggesting that changes in challenge appraisal in the week before the match were unrelated to in-match thriving.

The salivary cortisol and DHEA analyses were conducted with a sample subgroup. Specifically, the analyses focused on participants (n = 21) whose match was played in the early afternoon; the remaining participants were excluded as their match took place in the evening where

levels of cortisol and DHEA would be lower due to the diurnal rhythm of the hormones. The pre-match salivary cortisol values are displayed in Figure 1. Results from repeated measures ANOVA showed that cortisol levels were significantly different over time, $F(3, 60) = 8.85$, $p < .001$, $\omega^2 = 0.12$. Bivariate correlations revealed a small negative non-significant correlation between +5.25 hours cortisol concentration and thriving ($r = -.22$, $p = 0.355$, power = 0.17) and a moderate negative non-significant correlation between total cortisol exposure across the morning of the match and thriving ($r = -.32$, $p = 0.169$, power = 0.31). Furthermore, a small positive non-significant correlation was observed between + 5.25 hours DHEA concentration and thriving ($r = .28$, $p = 0.145$, power = 0.25). Finally, a non-significant relationship was found between the ratio of DHEA:cortisol and thriving in the + 5.25 hours sample ($r = .00$, $p = 0.991$, power = 0.07).

Discussion

This study examined whether levels of, and changes in, perceptions of BPNS and challenge appraisal predicted in-match thriving in elite athletes, and if salivary biomarkers related to thriving could be defined. BPNS and challenge appraisals reported immediately pre-match were shown to positively predict in-match thriving, with total cortisol exposure across the morning of the match, and cortisol and DHEA levels measured immediately pre-match shown to have small and moderate, albeit non-significant, associations with thriving.

The results show that athletes' daily perceptions of BPNS were stable in the week before the match, with levels of BPNS reported immediately pre-match positively predicting in-match thriving. Although scores of certain BPNS measures have been shown to support stability over-time,[37] the stability reported in the present study is in contrast to previous research reporting daily fluctuations in autonomy, competence, and relatedness in athletic groups[38] and the increase in BPNS that we hypothesized. Drawing from previous sport-based research that has reported moderate levels of stability for perceptions of coach autonomy support behaviors,[39] it is plausible that the stable levels of BPNS reported by athletes in the present study are indicative of consistency in coaching style and coach-player interactions, irrespective of the nature of daily interactions (i.e., in-person vs. remote) and the proximity of important matches. Despite previous theoretical suggestions that BPNS is a thriving prerequisite[2] and empirical evidence demonstrating a relationship in sport performers,[3] no

prospective studies had been conducted to verify this effect. Therefore, finding a significant prediction through prospective measurements represents a substantial advancement in the evidence for the role of BPNS on thriving. In so doing, this finding provides further empirical support for theoretical reasoning within SDT that the satisfaction of the three basic psychological needs reflects human thriving in the deepest sense.[2]

To our knowledge, this study also represents the first attempt to prospectively examine athletes' challenge appraisals in the week before a match. Thus, these data are the first to show that perceptions of challenge increase as a match approaches, with levels reported immediately pre-match positively predicting thriving. Finding increases in challenge appraisal as the match approached supported our hypothesis that players' thoughts about their sport representing an opportunity for growth would become more intense/apparent as it became closer. Interestingly, the absence of variability in this pattern across participants suggested that all players experienced a similar 'anticipatory rise' for the upcoming match. Notwithstanding these changes in challenge appraisals over the week, the rate of change was not predictive of thriving, suggesting that it is not how levels of challenge alter that impact whether athletes thrive; rather, it is the level of challenge reported immediately pre-match that is important for in-match thriving. Challenge appraisals have previously been found to directly elicit facilitative outcomes in sport performances,[40] and to indirectly impact performance and well-being through task engagement and effective coping.[41] Therefore , within the present study, players reported higher levels of challenge appraisal may have approached and engaged with the demands of the encounter in a facilitative manner, effectively overcame demands, and, ultimately, thrived. Whereas those who reported lower levels of challenge appraisal may have been more hesitant in their responses to the demands and have only managed or succumbed to them.

Previous research has suggested that thriving may manifest physiologically through an individual's hormonal response to a demanding situation.[14] The present study was the first to examine this suggestion in a performance setting and to hypothesize that pre-match salivary cortisol reactivity and salivary DHEA were potential biomarkers for thriving in sport. Although not statistically significant, the respective small and moderate negative correlations found between cortisol concentration and total cortisol exposure with thriving support Epel et al.'s[14] suggestion that a

dampened acute cortisol response to stress would be associated with thriving. Given that cortisol is released in response to stressors,[18] a smaller cortisol response in players who went on to thrive could be indicative of those individuals perceiving lower stressor dimensions or implementing more adaptive response mechanisms on the morning of the match. Notwithstanding this interpretation, it is important to acknowledge that exposure to chronic stress can also lead to a blunted cortisol response,[42] so it would be important in future work to further examine how ongoing stress exposure may impact these acute responses. Players' DHEA levels collected immediately pre-match had a small positive correlation with subsequent thriving supporting the proposed salutary effect of DHEA on well-being.[17] Although the mechanisms underlying the effects of DHEA remain unknown,[17] the results of this study add to the extant literature by demonstrating possible positive effects in athletic men when exposed to acute stress (i.e., pre-match demands). In contrast to considering salivary cortisol and DHEA independently, anabolic balance (i.e., the ratio of salivary DHEA:cortisol in the + 5.25 hours sample) showed no association with thriving; this result challenges previous suggestions of a role of anabolic balance in thriving.[14] The inconsistent findings for the relationships of DHEA concentration and DHEA:cortisol ratio with thriving may suggest that different processes exist for these salivary measures in response to stress.

Despite the notable strengths of this study in terms of its originality (i.e., the first prospective study of thriving in sport to examine potential salivary biomarkers for thriving) and significance for practice (i.e., informing the promotion of performance and well-being in sport), the applied context within which the study was conducted raised some limitations with regards to the statistical power in some analyses. First, the asynchronous timing of one of the fixtures meant that it was not possible to include data from all participants in the analysis of the salivary variables. As a result, and based on the reported effect sizes, power analyses indicated that the chances of finding statistically significant effects for the salivary analyses—assuming that they existed—ranged between 7 and 31%. Second, despite recruiting players from a significant proportion of the elite teams available for the study, some analyses in the more complex LGM lacked statistical power suggesting that null hypotheses may have been incorrectly accepted for some results. Given that power within LGMs varies contingent not just on the sample size, but also due to missing data, parameter values, and the number of time points,[43]

the absence of known parameter estimates and missing data patterns meant that it was not possible to conduct an a priori power calculation for this study. Researchers are encouraged to use the estimates and response patterns reported herein to inform sample size calculations and improve power in future work and, in so doing, reduce the risk of false positive and false negative findings. Third, awakening was not controlled by the researchers to encourage compliance and allow the players to follow their typical match-day routine. Instead, accelerometry was used to record sleep times and verify the time of awakening. Not all participants adhered to wearing the accelerometer due to experiencing discomfort and subsequent disturbed sleep. Thus, it was not possible to verify waking time for all participants. Fourth, it is possible that the relationships between the variables recorded pre-match and thriving assessment collected post-match were influenced by in-match events and experiences (e.g., confrontation with a teammate or coach). Although it is not feasible to collect self-reported measures of such factors during a competitive match in a continuous sport like hockey, sports with regular breaks in play (e.g., tennis and golf) may afford researchers with better opportunities to capture these experiences through brief, self-report scales. Fifth, the LGM showed that basic psychological need satisfaction and challenge appraisal explained 13% and 11% of the variance in thriving, respectively. It is therefore important that future research also considers the predictive effects of additional inter-individual variables as well as pertinent interpersonal factors.

Conclusion

This study found that levels of BPNS and challenge appraisals reported immediately before a sporting encounter positively predicted in-match thriving. This prospective work advances knowledge gleaned from cross-sectional studies, with findings offering coaches and sport science and sports medicine practitioners potential mechanisms through which they can facilitate both high-level performance and the experience of well-being. The research also represented the first examination of salivary biomarkers for thriving, with total cortisol exposure across the morning of the match, and cortisol and DHEA levels measured immediately pre-match representing potential early detection mechanisms for subsequent athlete thriving.

Practical Implications

- Promoting elite athletes' feelings of autonomy, competence, and relatedness, and developing their interpretations of sport as an opportunity for growth, may enable them to experience enhanced in-match performance and well-being.
- The measurement of salivary cortisol and dehydroepiandrosterone pre-match may offer practitioners prior indication of whether players are expected to thrive.

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Table 1. *Descriptive Statistics for Psychological Process Variables, Biomarkers Variables, and Thriving Indicators*

Variable	6 days		5 days		4 days		3 days		2 days		1 day		Pre-match		Post-match	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Psychosocial Process Variables																
BPNS (1-7)	6.32	0.63	6.22	0.78	6.01	0.78	6.14	0.75	6.22	0.52	6.19	0.69	6.27	0.62		
Challenge appraisal (1-7)	6.10	0.74	6.19	0.76	6.08	0.93	6.18	0.90	6.33	0.66	6.30	0.76	6.31	0.73		
Salivary Biomarker Variables (μg/dL)																
Pre-match cortisol (+ 5.25 sample)													0.31	0.17		
Pre-match DHEA (+ 5.25 sample)													0.02	0.01		
Total cortisol exposure													94.82	31.36		
Thriving Indicators																
Subjective performance (0 – 10)															5.71	1.93
Subjective vitality (1-6)															4.86	0.75
Positive affect (1-5)															4.13	0.52

Table 2. *Latent Growth Model Fit Statistics*

	Fit Indices				
Model	AIC	BIC	CFI	TLI	RMSEA [90% CI]
Basic Psychological Need Satisfaction					
Intercept-only	237.78	253.84	0.94	0.95	.13 [.06, .19]
Linear[a]	242.69	264.10	0.94	0.94	.14 [.08, .21]
Challenge Appraisal					
Intercept-only	337.46	353.52	0.96	0.97	.09 [.00, .16]
Linear	333.14	354.55	0.99	0.99	.06 [.00, .14]
Quadratic	331.56	360.11	1.00	1.00	.00 [.00, .11]

Note. AIC = Akaike's information criterion; BIC = Bayesian information criterion; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; CI = confidence interval.
[a]The covariance matrix of the latent growth factors was not a proper covariance matrix. The problem was associated with the growth factor *Slope*. The variance of this variable is very small and not statistically significant ($Var_s < .001$, $z = 0.09$, $p = .815$). In addition, the correlation between the intercept and linear growth factors was estimated to be -1.14, which is an inadmissible value for a correlation coefficient. Thus, the model fit statistics and model results may not be accurate.

Figure Captions

Fig 1 Mean concentration of salivary cortisol measured at each time-point. Error bars = standard error of mean.